A PRESSURE SCANNING FABRY-PEROT MAGNETOMETER*

T.D. Fay and A.A. Wyller

Bartol Research Foundation of The Franklin Institute
Swarthmore, Pennsylvania 19081

In order to understand more fully the operation of our magnetometer, it is necessary to describe in some detail the construction of the spectrometer to which the magnetometer is attached. The Bartol spectrometer has been planned with the view in mind to provide a completely self-contained, mobile, high resolution spectrometer equivalent in performance to several conventional coudé spectrograph camera assemblies with a variety of spectral resolutions and wavelength coverages. Briefly speaking the design goals have been the full utilization of the light of solar surface features or stellar images (diameters 2"-4") anywhere in the wavelength range 4000 to 12,000Å with spectral resolutions continuously variable from 10^3 to 10^6 and dual channel pulsecounting facilities.

The integrated Fabry-Perot spectrometer which has been developed at Bartol to meet these demands consists of four subassemblies: a) a Fabry-Perot interferometer, b) a predispersing echelle spectrograph, c) a combined pressure chamber and

* Work supported by NASA Grant NGR-39-005-066

pressure control system, d) a dual channel pulse counting system.

The servo-controlled Fabry-Perot interferometer of Ramsay's design uniquely provides the required versatility in spectral resolution and wavelength coverage with one and the same instrument. Two pairs of interferometer plates cover the spectral range $\lambda\lambda$4000-12000 with an effective finesse of 30. The plate separations can be varied continuously from one tenth to one hundred millimeters and the plates are maintained parallel to $\lambda/80$ by electronic servo controls. The geometrical plate separation is maintained to an accuracy of 10Å also by servo controls.

The Fabry-Perot interferometer necessitates a predispersing unit to filter out adjacent passbands. To this end a Hilger-Engis monochromator (Model 600) has been modified at the factory to permit installation of a Bausch and Lomb echelle grating (300 lines/mm, blazed at 63°26'). This eliminates the need for grating changes in covering the above broad wavelength interval. Overlapping orders are separated by suitable broadband interference filters.

The pressure chamber (cylindrical with 2 feet diameter and 4 feet length) is mounted on a heavy table, which rolls easily but can be firmly jacked up from the floor for steady coupling by laser means to a given telescope coudé configuration. The installation of remote controls (externally on the pressure chamber) for the parallelism adjustment of the interferometer plates and the tilt variations of the grating have been carried out. This eliminates the need for opening the pressure chamber every time readjustments of the plates and changes to other wavelengths or spectral resolutions are required. A system of 6 entrance and exit pinholes (2, 0.4, 0.2, 0.1, 0.05 and 0.025 mm) moveable by micrometer screws have also been installed and are remotely controlled.

The pressure generator and controller has been acquired from the Texas Instrument Co. Its unique precision in control and setting (to a few hundredths of a mm Hg) enables one to use freon gas with five times more sensitive variations in the index of refraction to pressure variations than air, which has been most commonly used in astronomical applications. The pressure chamber has been designed for pressure scanning over 4 atmospheres, which yields in the visual a spectral scan width of about 20 Angströms. The servo-controlled pressure generator does not involve continuous leakage but enables one to remain at a given pressure level and pulse count to the required precision. At the NaD-line a pressure change of 0.1 inch Hg moves the spectrometer passband 0.02Å.

Pulse counting facilities have been developed for counting at low light levels (10-100 counts per second). The EMI9529 photomultiplier tube records the intensity of the line element under consideration and is dry-ice cooled. The echelle spectrograph, by the use of a beam splitter, permits one to monitor a 50Å wide continuum strip inside the pressure chamber while having it centered on the line feature wherever in the spectrum one may wish to operate. This second channel serves as a sunspot guiding monitor. A third broadband channel outside the entrance pinholes is utilized for the monitoring of transparency changes.

The Bartol magnetometer is a one slit system which has the advantage of simplicity and reduces the difficulty of the "Doppler error" in multi-slit-systems. The penalty for this choice of system lies in the problem of eliminating the instrumental polarization, which however seems possible to overcome in simple mirror-lens systems.

Furthermore, the double-slit method only eliminates circular polarization. If the linear polarization component is to be measured, elimination techniques similar to those for the one-slit-system have also to be employed, which can be achieved either through a phase compensator or by a direct measurement of the instrumental linear polarization. Since the Bartol system uses a 15-inch siderostat (diaphragmed down to 4 inches) with a single plane mirror feeding the objective lens-doublet, the instrumental polarization characteristics are rather simpler than in the multi-mirror systems of tower telescopes or conventional stellar coudé-configurations.

An unusual advantage of the present spectrometer, which has overridingly dictated the choice of a single slit-system, is the capability it gives for pressure scanning through the entire profiles of all the Zeeman components. This will yield information on the variation of the magnetic field with optical depth, i.e. the magnetic field gradients, which are so important for the construction of realistic spot models. This is very difficult if not impossible with a two-slit system which requires perfect symmetry about line center in the placement of the two slits. In our simple system with a bandpass of 0.02Å for the Fabry-Perot echelle combination we typically record for the spot continuum 1,000 counts/second with the magnetic analyzer in position and an entrance aperture of 2 seconds of arc (50 micron entrance and exit pinhole apertures).

The magnetic analyzer consists of a KD*P (KD_2PO_4) crystal with 80% transmission over the wavelength range 4000 to 13000Å and a half-wave voltage of 4.0 Kv at λ5000. It thus can act as a quarter-wave or half-wave plate over a wide wavelength region. It is followed by a Glan-Thompson prism, which acts as an analyzer at 45° to the KD*P plate. The complete magnetometer transmits about 25% of the sunspot beam intensity. Both are placed immediately in front of the spectrograph optics, just behind the entrance pinhole, to eliminate the instrumental polarization due to the spectrograph itself.

For the measurement of circularly polarized components the voltage to the KDP crystal will oscillate at a frequency of about 15 c/sec to minimize the effects of transparency fluctuations. The difference count between lefthand and right-hand circularly polarized light will be recorded at each wave-length passband.

In order to measure the linearly polarized light, the Glan-Thompson prism will rotate also at about 15 c/sec and the resulting ac-signal will be recorded by a pulsecounter. Under consideration are also broad and narrow band depolar-izers to eliminate residual polarizations in the glass sur-faces of the photomultiplier tubes.

A complete description of the general instrument will appear in Applied Optics.